Review Article

My Approach to Echocardiographic Assessment of Left Ventricular Filling Pressures: From Ambiguity to Precision With New Guidelines

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Abstract

The echocardiographic estimation of left ventricular (LV) filling pressures is a cornerstone in the assessment of heart failure, particularly in patients with heart failure with preserved ejection fraction (HFpEF). The 2016 American Society of Echocardiography/European Association of cardiovascular Imaging algorithm standardized this evaluation using key variables, but a substantial proportion of cases remained indeterminate in clinical practice. The recent update of the American guideline reorganized the approach into a hierarchical framework, incorporating age-related adjustments and formalizing the role of left atrial strain (LAS) as a tie-breaking parameter, while also providing a more detailed characterization of special clinical scenarios. In parallel, the 2024 British Society of Echocardiography guideline emphasizes the pathophysiological interpretation of ventricular filling, complementing the operational framework proposed by the American document. Multicenter studies with invasive validation support these updates, establishing LAS as a robust marker of increased filling pressures. In this article, we present My Approach to echocardiographic assessment of LV filling pressures, based on an initial morphofunctional evaluation, followed by structured screening (Step 1) and further refinement (Step 2) incorporating LAS and additional parameters. We also provide a comparison between guidelines, discuss common pitfalls and algorithm limitations, and include case-based videos for practical application.

Introduction

The echocardiographic assessment of left ventricular (LV) filling pressures has evolved from a mitral Doppler-centered approach to an integrated model incorporating both morphological and functional parameters, supported by increasingly structured algorithms. The 2016 American Society of Echocardiography (ASE)/European Association of cardiovascular Imaging (EACVI) guideline for assessing LV diastolic function by echocardiography marked a pivotal step in this transition by proposing a simplified framework based on four core variables;[1] however, a substantial proportion of examinations remained indeterminate with respect to filling pressure estimation. This limits diagnostic accuracy, particularly in conditions such as heart failure with preserved ejection fraction (HFpEF).

In addition, specific clinical conditions (e.g., atrial fibrillation [AF], pulmonary hypertension, and valvular heart disease) have continued to pose challenges to the applicability and interpretation of these parameters.[2]

Recent updates have advanced this field along two complementary directions. The 2024 British Society of Echocardiography guideline for assessing LV diastolic function[3] reinforces the pathophysiological basis of ventricular filling and formalizes left atrial strain (LAS) as a refinement tool. In parallel, the ASE 2025 update reorganizes the decision-making process, incorporates age-related adjustments, and integrates atrial strain in a similar manner,[4] supported by multicenter studies with invasive validation (Table 1).[5]

This article translates these advances into daily clinical practice through My Approach to echocardiographic assessment of LV filling pressures, an approach designed to be practical, reproducible, and clinically meaningful while preserving a strong physiological foundation (Central Illustration).

Before the algorithm: the integrated view of the echocardiographer

The assessment of diastolic function should always begin with clinical contextualization (e.g., age, symptoms, cardiac rhythm, valvular heart disease, and hemodynamic status) because the algorithm addresses a specific clinical question and should not be applied indiscriminately.[3,4]

Before applying any flowchart, a two-dimensional morphofunctional assessment allows the echocardiographer to rapidly integrate patterns of hypertrophy, LA size, ventricular geometry, mitral annular motion, signs of pulmonary hypertension, and the overall visual impression of ventricular compliance. This approach enables the clinician to position the patient within a probable phenotype: low, intermediate, or high likelihood of increased filling pressures.

This initial impression does not replace the algorithm; rather, it prevents both the mechanical application of numerical thresholds and conclusions drawn without objective criteria. It serves as a conceptual framework that

Keywords

Left Ventricular Function; Echocardiography; Heart Failure

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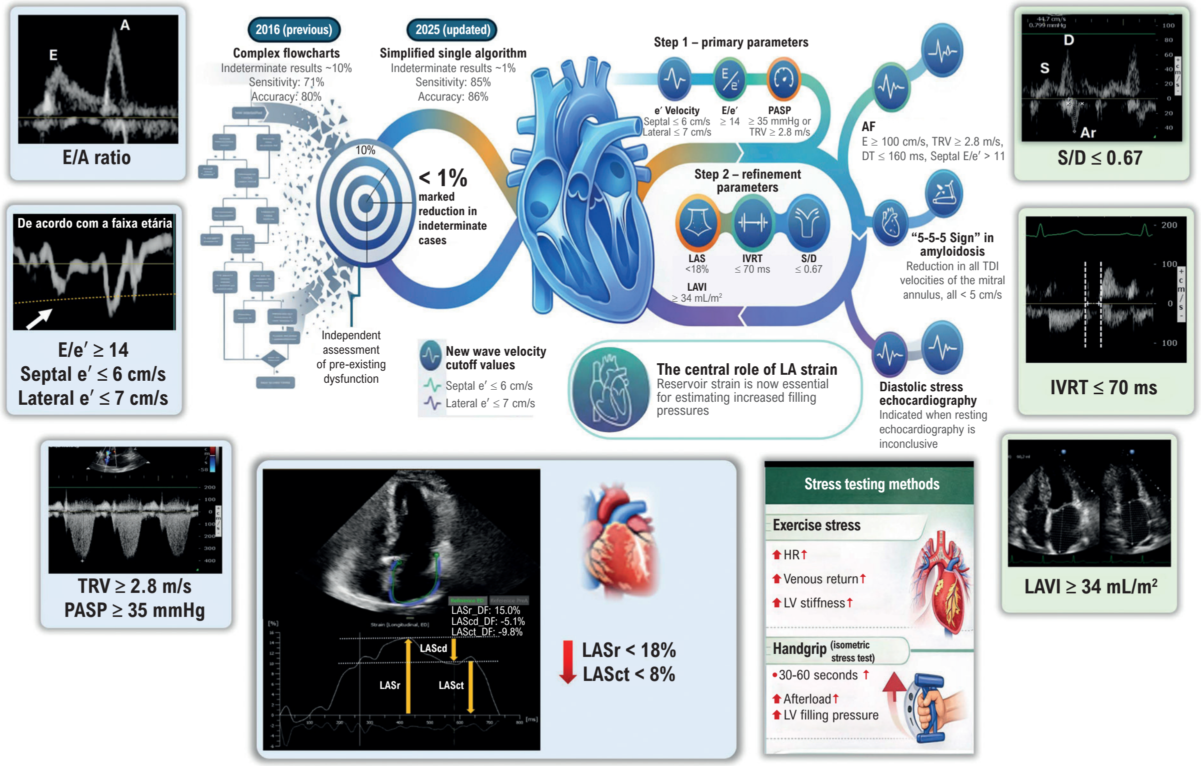
Manuscript received March 12, 2026, revised manuscript March 23, 2026, accepted March 25, 2026
Editor responsible for the review: Marcelo Tavares

DOI: https://doi.org/10.36660/abcimg.20260026i

Central Illustration: My Approach to Echocardiographic Assessment of Left Ventricular Filling Pressures: From Ambiguity to Precision With New Guidelines



Arq Bras Cardiol: Imagem cardiovasc. 2026;39(2):e20260026

Integration and hierarchical application of parameters and techniques for the evaluation of LV filling pressures. The strategy begins with morphofunctional assessment and structured screening, followed by targeted refinement in indeterminate or discordant cases (Step 2), in which LAS and complementary parameters play a decisive role in the final diagnostic classification. AF: atrial fibrillation; DT: deceleration time; ED: end-diastole; HR: heart rate; IVRT: isovolumetric relaxation time; LAS: left atrial strain; LAScd: left atrial conduit strain; LASct: left atrial contraction strain; LASr: left atrial reservoir strain; LAVI: left atrial volume index; LV: left ventricular; PASP: pulmonary artery systolic pressure; TDI: tissue Doppler imaging; TRV: tricuspid regurgitation velocity.

guides interpretation and may be refined or corrected by the structured model.

Strategy overview: two steps, one clinical question

The assessment should be structured to answer a simple and clinically meaningful question: Is there consistent evidence of increased LV filling pressures? Table 2 summarizes the parameters used for this evaluation.

Step 1: initial screening

Updated guidelines emphasize that aging is associated with a physiological decline in myocardial relaxation. As a result, values considered abnormal in younger individuals may be expected in older people. Therefore, an isolated reduction in e′, particularly in older people, should not be automatically interpreted as indicative of increased filling pressures. Age-adjusted reference values are essential to support this interpretation.[4]

i. e′ velocity: relaxation with age adjustment

Both septal and lateral e′ velocities should be routinely assessed. A decreased e′ suggests impaired relaxation but does not necessarily indicate increased filling pressures, particularly in older individuals, in whom lower values are common and may occur in the presence of normal pressures.[3] Thus, e′ is highly informative for characterizing relaxation but must be interpreted in conjunction with other parameters.

New/current concept: the 2025 guideline refines normal reference thresholds and acknowledges that septal e′ ≤ 6 cm/s or lateral e′ ≤ 7 cm/s is frequently observed in individuals aged

Table 1 – Comparison between guidelines and recent evidence

Domain	ASE/EACVI (2016)[1]	ASE (2025)[4]	BSE (2024)[3]	My Approach to integration in practice
Objective	Standardization and simplification	Reduction of discordance and indeterminate cases; hierarchical framework	Emphasis on pathophysiology and interpretation	Integration of the 2025 framework with BSE physiological principles, using the 2016 model as the foundation
LAS	Not formally included	Formalized as a refinement parameter	Formalized as a refinement parameter	Preferred tie-breaking parameter
Age adjustment	Limited	Explicit incorporation	Recognized	Avoid overdiagnosis in older patients
LAVI	Core parameter	Supportive parameter; marker of chronicity	Structural parameter	Contextual support; not used in isolation
Gray zone	Frequent	Structured resolution strategy	Physiological interpretation	Step 2 refinement (LAS, IVRT, pulmonary venous flow)

ASE: American Society of Echocardiography; BSE: British Society of Echocardiography; EACVI: European Association of Cardiovascular Imaging; IVRT: isovolumetric relaxation time; LAS: left atrial strain; LAVI: LA volume index; PV: pulmonary vein.

Table 2 – Reference parameters for the assessment of LV filling pressures

Parameter	Abnormal threshold	Clinical interpretation/Action
Septal e′ velocity	≤ 6 cm/s	Decreased values suggest impaired relaxation; should be interpreted alongside other parameters.
Lateral e′ velocity	≤ 7 cm/s	Same interpretation as septal e′; should be interpreted alongside other parameters.
E/A ratio	≤ 0.8 or ≥ 2.0	E/A < 0.8 suggests impaired relaxation; E/A ≥ 2.0 suggests a restrictive filling pattern (should be interpreted alongside other parameters).
Average E/e′ ratio	≥ 14	Supports the presence of increased filling pressures.
PASP/TR velocity	≥ 35 mmHg / ≥ 2.8 m/s	When increased, supports increased filling pressures in the absence of pre-capillary pulmonary hypertension.
LASr	< 18%	Decreased values favor increased filling pressures; primary tie-breaking parameter.
LASct	< 8%	Marked decrease supports sustained increase of filling pressures; normal values may help exclude increased pressures (particularly when LASct > 14% and GLS ≥ 18%).
IVRT	< 70 ms	Shortened IVRT suggests increased filling pressures.
S/D ratio (pulmonary vein)	< 0.67	Diastolic predominance supports increased filling pressures; stronger association in decreased LVEF.
Ar-A difference (pulmonary vein)	> 30 ms	Suggests increased filling pressures, particularly in hypertrophic cardiomyopathy and MR.
LAVI	> 34 mL/m^2	Indicates chronic exposure to increased filling pressures; not diagnostic in isolation.
Diastolic stress echocardiography	Exercise E/e′ > 14; TR velocity > 2.8 m/s	Indicated when resting echocardiography does not explain symptoms; supports dynamic increase of filling pressures.
LUS/VExUS (adjunctive)	IVC > 2 cm; reversed hepatic/portal flow; B-line grading 0-3	Complementary assessment when clinical and imaging findings are discordant and resting echocardiography is inconclusive.

GLS: global longitudinal strain; IVC: inferior vena cava; IVRT: isovolumetric relaxation time; LASct: left atrial contractile strain; LASr: left atrial reservoir strain; LAVI: left atrial volume index; LUS: lung ultrasound; PASP: pulmonary artery systolic pressure; TR: tricuspid regurgitation; VExUS: venous excess ultrasound score; MR: mitral regurgitation.

> 60-70 years and, in isolation, does not define increased filling pressures.[4]

ii. *E/e′ ratio: useful but not definitive*

The E/e′ ratio remains a cornerstone parameter due to its practicality; however, it should be interpreted as supportive evidence rather than a standalone determinant.[3,4]

New/current concept: an average E/e′ ≥ 14 supports the presence of increased filling pressures, whereas lower values make this less likely. However, an intermediate "gray zone" (particularly 8-14) is common and, according to the 2025 guideline, requires further refinement using additional parameters. Limitations must also be recognized in the presence of significant mitral valve disease, irregular rhythms without adequate beat averaging, and ventricles with preserved ejection fraction.[5,6]

iii. *Tricuspid regurgitation velocity (TRV): a link to pulmonary hemodynamics*

When adequately measured, TRV provides an indirect estimate of pulmonary pressure and may support the presence of increased LV filling pressures (post-capillary), provided that primary pulmonary disease (pre-capillary) is excluded. The cutoff of ≥ 2.8 m/s remains consistent across recent guidelines.[3]

New/current concept: the ASE update also considers an estimated pulmonary artery systolic pressure (PASP) ≥ 35 mmHg as suggestive of increased filling pressures, provided that right atrial pressure estimation based on inferior vena cava parameters is technically reliable.[4]

Step 2: refinement — where the recent updates have truly shifted practice

Step 2 focuses on the assessment of LA/LV remodeling markers and indicators of increased filling pressures.

i. *E/A ratio and deceleration time (DT): the mitral pattern still matters*

The E/A ratio remains a central physiological marker of transmitral filling, guiding the distinction between impaired relaxation and decreased compliance.[1] An E/A ratio ≤ 0.8 suggests impaired relaxation (common with aging), whereas E/A ≥ 2.0 combined with DT < 160 ms (particularly in patients with decreased LVEF) indicates a restrictive filling pattern and increased pressures.

The main limitation is pseudonormalization (E/A 0.8-2.0 in the presence of increased pressures), which underscores that E/A should never be interpreted in isolation.

New/current concept: the 2016 guideline emphasized its role in grading diastolic dysfunction, and the 2025 update preserves its physiological relevance while prioritizing a more objective and reproducible decision-making framework.[4]

ii. *Left atrial volume index (LAVI): a marker of chronic exposure rather than current pressure*

LAVI > 34 mL/m^2 is a well-established marker of chronic LA exposure to increased filling pressures, with important diagnostic and prognostic value in HF, AF, valvular heart disease, and cardiomyopathies.[7-9]

New/current concept: in the 2025 update, LAVI is no longer a central parameter but assumes a supportive role since it reflects chronic remodeling rather than current hemodynamic status. Therefore, it should be interpreted alongside markers that are less influenced by transient changes.

iii. *Left atrial strain (LAS) (reservoir and contractile): the key contemporary tie-breaker*

Recent studies have demonstrated a strong correlation between LAS and invasive measures of filling pressure, establishing left atrial reservoir strain (LASr) as a marker of increased pressures and left atrial contractile strain (LASct) as a tool to exclude them.[10,11]

New/current concept: atrial strain represents the most relevant practical innovation in current guidelines since it captures both LA function and hemodynamic history. LASr < 18% (particularly < 16%) suggests increased filling pressures by reflecting decreased atrial compliance, whereas LASct > 14% in patients with preserved EF effectively excludes increased pressures, even in the presence of borderline E/e′ values.[4,10]

Technical acquisition: LAS should be measured in apical four- and two-chamber views, with the R-R interval defining the cardiac cycle. Adequate frame rates (> 60 fps), appropriate depth, and optimized image acquisition are essential. Speckle-tracking analysis should exclude pulmonary veins and the LA appendage. The average of both views should be reported (Figure 1, Video 1).

iv. *Isovolumetric relaxation time (IVRT): useful in discordant or challenging scenarios*

IVRT corresponds to the interval between aortic valve closure and mitral valve opening, reflecting early active ventricular relaxation.[12]

New/current concept: initially described as an auxiliary parameter in the 2009 guidelines and maintained as a complementary measure in 2016, IVRT has regained relevance as a refinement tool in discordant cases. Although not part of the primary decision-making core, a shortened IVRT (≤ 70 ms) suggests increased filling pressures, particularly when associated with a restrictive filling pattern or decreased atrial strain. It is especially useful when tissue Doppler measurements are unreliable, such as in AF or mitral annular calcification.[4]

v. *Pulmonary venous flow (S/D and Ar-A): when additional confirmation is needed*

Pulmonary venous flow assessment can be technically challenging but provides valuable information when adequately acquired. A diastolic predominance (S/D ≤ 0.67) supports increased filling pressures. However, patients with

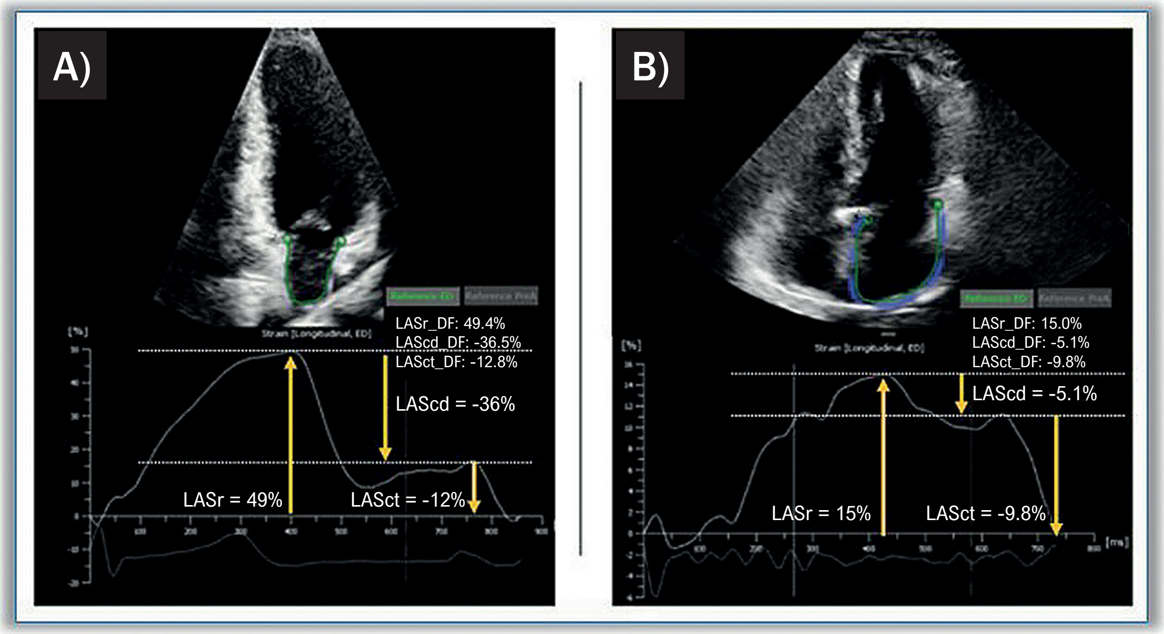


Figure 1 – *Role of LAS in refining the assessment of LV filling pressure. Assessment of LA deformation using speckle-tracking echocardiography. A) LASr, LAScd, and LASct measurements in a normal subject, with values of 49%, −36%, and −12%, respectively; B) corresponding strain curves from a patient with increased filling pressures, showing values of 15%, −5.1%, and −9.8%, respectively. LA: left atrium; LAS: LA strain; LAScd: LA conduit strain; LASct: LA contractile strain; LASr: LA reservoir strain; LV: left ventricle.*

preserved LVEF may exhibit S/D > 0.67 despite increased pressures, requiring confirmation with additional parameters.

An Ar-A duration difference > 30 ms may be useful in selected conditions, such as hypertrophic cardiomyopathy and mitral regurgitation (MR).[3,4,13]

vi. Additional supplementary parameters

When primary and refinement parameters are unavailable or unreliable, additional measures may support clinical interpretation. These include: peak diastolic pulmonary regurgitation velocity ≥ 2 m/s; pulmonary artery diastolic pressure ≥ 16 mmHg; mitral inflow L-wave velocity ≥ 50 cm/s; Ar-A duration > 30 ms; ≥ 50% reduction in mitral E/A during the Valsalva maneuver; E/Vp ≥ 2.5; A-wave transit time ≤ 45 ms; and IVRT/TE e′ < 2.

In addition, an LV mass index > 95 g/m^2 in women or > 115 g/m^2 in men may indicate structural remodeling consistent with diastolic dysfunction.[3,4]

Interpretation and integration of parameters (algorithm-based approach)

If all primary parameters assessed in Step 1 (e′, TRV, and E/e′) are within normal limits, LV filling pressures are considered normal. Conversely, if all three parameters are abnormal, increased filling pressures are present.

When e′ is decreased (based on age-adjusted reference values) and the E/A ratio is ≤ 0.8, this pattern is consistent with grade I diastolic dysfunction and normal filling pressures.

Diagnostic uncertainty arises in intermediate or discordant scenarios, including cases in which only e′ is decreased with E/A > 0.8, isolated increase of TRV/PASP or E/e′, or when any two primary variables are abnormal. In these situations, refinement using Step 2 parameters becomes essential.

These include LASr, IVRT, S/D, LAVI, and additional supplementary parameters. If one or more of these refinement markers are abnormal, increased filling pressures are confirmed. An E/A ratio < 2 supports the classification of grade II diastolic dysfunction, whereas E/A ≥ 2 indicates grade III diastolic dysfunction.[4]

Figure 2 shows the application of the algorithm.

Special situations

The 2025 guideline reinforces that a "one-size-fits-all" approach is not applicable. Specific clinical scenarios require adaptation of both acquisition and interpretation strategies (Table 3).

i. AF

Beat-to-beat variability increases the risk of measurement error; therefore, averaging multiple cardiac cycles is essential. Ideally, measurements should be obtained at a controlled heart rate < 100 bpm. Patients with decreased variability in mitral inflow tend to have increased filling pressures (Figure 3).[3,14]

My Approach to AF: the assessment follows a two-step framework. In Step 1, the following parameters are considered: E ≥ 100 cm/s, septal E/e′ ≥ 11, TRV > 2.8 m/s or PASP > 35 mmHg, and DT ≤ 160 ms.

If none or only one parameter is abnormal, filling pressures are considered normal. If ≥ three parameters are abnormal, filling pressures are increased. If two parameters are abnormal, refinement is required using Step 2 markers, including LASr < 18% and S/D < 1. BMI > 30 kg/m^2 further supports the diagnosis of HFpEF.

An average of 5-10 cardiac cycles should be used. If none of the parameters are abnormal, filling pressures are normal. If two of the three refinement parameters are abnormal, increased filling pressures are present. If only one parameter is abnormal or data are unavailable, the result should be considered indeterminate.

Caution: LASct is not present in AF; however, LASr remains informative. Very low values (< 16%) indicate decreased atrial compliance and increased filling pressures (Video 2).

ii. Mitral valve disease

In mitral stenosis, the E/e′ ratio should not be used. In significant MR, the E-wave may be increased due to volume overload rather than increased filling pressures.[3,4,15]

My Approach to mitral valve disease: in MR, greater emphasis should be placed on pulmonary venous flow patterns and IVRT. LAS should be interpreted cautiously, as regurgitant volume may artificially increase LASr.

iii. Cardiac amyloidosis

In this setting, isolated numerical values may fail to capture the underlying pathophysiology; the two-dimensional phenotype and overall functional pattern are key determinants. The presence of increased LV wall thickness associated with an "apical sparing" pattern on longitudinal strain should prompt evaluation for a restrictive diastolic filling pattern.[3,16]

My Approach to cardiac amyloidosis: a characteristic dissociation is often observed, with markedly decreased e′ velocities (septal and lateral < 5 cm/s) in contrast to a

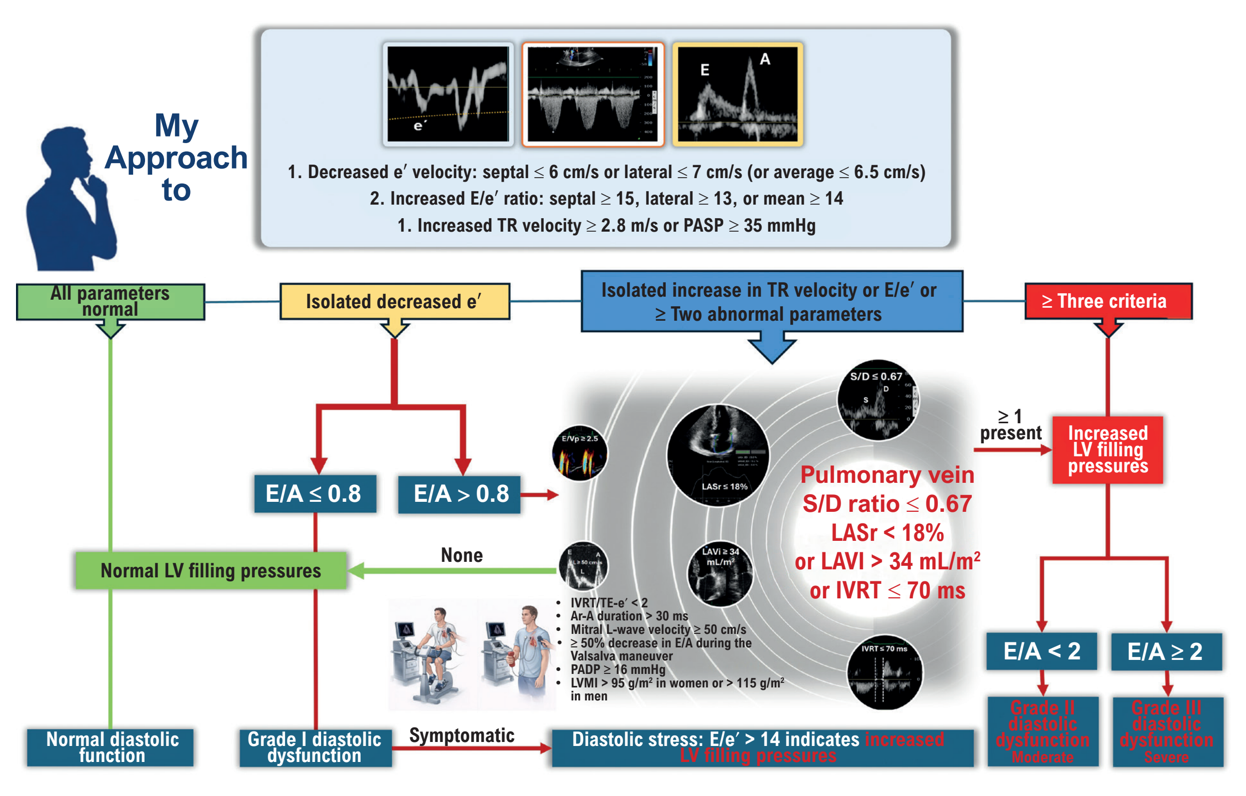


Figure 2 – *Decision algorithm for estimating LV filling pressures. Practical flowchart based on the 2025 ASE guideline. Step 1 relies on core parameters of myocardial relaxation and filling pressure assessment. In cases of discordance (e.g., a single abnormal parameter or borderline values), Step 2 is applied, prioritizing LASr and IVRT. Integration of these findings allows both grading of diastolic dysfunction and definitive classification of LV filling pressure status. ASE: American Society of Echocardiography; IVRT: isovolumetric relaxation time; LASr: left atrial reservoir strain; LAVI: left atrial volume index; LV: left ventricle; LVMI: LV mass index; PADP: pulmonary artery diastolic pressure; PASP: pulmonary artery systolic pressure; TR: tricuspid regurgitation.*

Table 3 – Clinical conditions requiring adaptation of the standard diastolic function algorithm

Clinical condition	Key considerations for assessing LV filling pressure
AF	Average 5-10 consecutive beats at a controlled heart rate. Consider E ≥ 100 cm/s, septal E/e′ ≥ 11, TR velocity ≥ 2.8 m/s, and DT ≤ 160 ms. LASr < 18% supports increased filling pressures. LA volume alone is not diagnostic.
Mitral stenosis	E/e′ should not be used. Prioritize IVRT, TE-e′ ratio, and mitral A-wave velocity. Filling pressures should be interpreted cautiously due to transmitral obstruction.
MR	The E wave is often increased due to volume overload rather than increased pressure. E/e′ may overestimate filling pressures. Ar-A duration and IVRT may provide supportive information.
Mitral annular calcification	Mechanical restriction reduces the reliability of e′. Greater emphasis should be placed on IVRT and the overall filling pattern rather than E/e′ alone.
Cardiac amyloidosis	Markedly decreased annular velocities (“5-5-5” sign: s′, e′, a′ < 5 cm/s) combined with a restrictive transmitral pattern. Apical sparing on longitudinal strain supports the diagnosis.
Sinus tachycardia/high-output states	Increased transmitral velocities may reflect increased cardiac output rather than increased filling pressures. IVRT and E/e′ should be interpreted within the clinical context.
Heart transplantation	Altered atrial geometry, denervation, and frequent sinus tachycardia modify Doppler patterns. Early diastolic predominance may be physiological, particularly in younger donors.
LVAD	Continuous-flow physiology alters conventional Doppler indices. E/A, E/e′, and pulmonary pressures should be interpreted in the context of device settings and clinical status.
Restrictive cardiomyopathy vs constrictive pericarditis	Preserved or increased medial e′ (> 8 cm/s) favors constriction, whereas decreased e′ (< 6 cm/s) supports restrictive cardiomyopathy. Assess for annulus reversus and respiratory variation.
Hypertrophic cardiomyopathy	LVOT obstruction and significant mitral regurgitation may increase LA pressure. Ar-A duration, LAVI, and TR velocity should be integrated into the assessment.
Pulmonary hypertension	Septal E/e′ may be misleading in RV pressure overload. Prefer lateral e′ and LAS to differentiate pre- vs post-capillary mechanisms.
Conduction abnormalities (LBBB, RV pacing, CRT)	Abnormal septal motion reduces the reliability of e′ and E/e′. Greater weight should be given to TR velocity, LA size, and LAS.
Athlete’s heart	Physiological chamber enlargement and increased diastolic volume may mimic diastolic dysfunction. Emphasize absence of symptoms, normal natriuretic peptides, and preserved LAS. Avoid automatic grading.

CRT: cardiac resynchronization therapy; DT: deceleration time; IVRT: isovolumetric relaxation time; LA: left atrium; LAS: LA strain; LASct: LA contractile strain; LASr: LA reservoir strain; LAVI: left atrial volume index; LBBB: left bundle branch block; LVAD: left ventricular assist device; LVOT: left ventricular outflow tract; RV: right ventricle; TR: tricuspid regurgitation; AF: atrial fibrillation; MR: mitral regurgitation.

high mitral E-wave and shortened DT. This classic restrictive pattern strongly supports the presence of increased filling pressures, often obviating the need for complex algorithmic assessment.

iv. Pulmonary hypertension

The E/e′ ratio, particularly the septal measurement, may be misleading in pre-capillary pulmonary hypertension. In such cases, greater emphasis should be placed on the lateral E/e′ and on LAS, especially when distinguishing pre- from post-capillary mechanisms in borderline scenarios[3,4,17] (Video 3).

The role of diastolic stress testing and invasive hemodynamic assessment

In patients with exertional dyspnea (New York Heart Association classes II and III) and a resting echocardiography that is normal or indeterminate, even after incorporation of LAS, evaluation should not be discontinued.[3,4,18]

Diastolic stress echocardiography using a supine bicycle or treadmill is recommended.[3,4] Maneuvers that increase LV preload, such as passive leg raising, may also help unmask increased filling pressures in patients with decreased ventricular compliance. These approaches may serve as alternatives when formal exercise testing is unavailable, although a negative result does not exclude clinically significant diastolic dysfunction.[3]

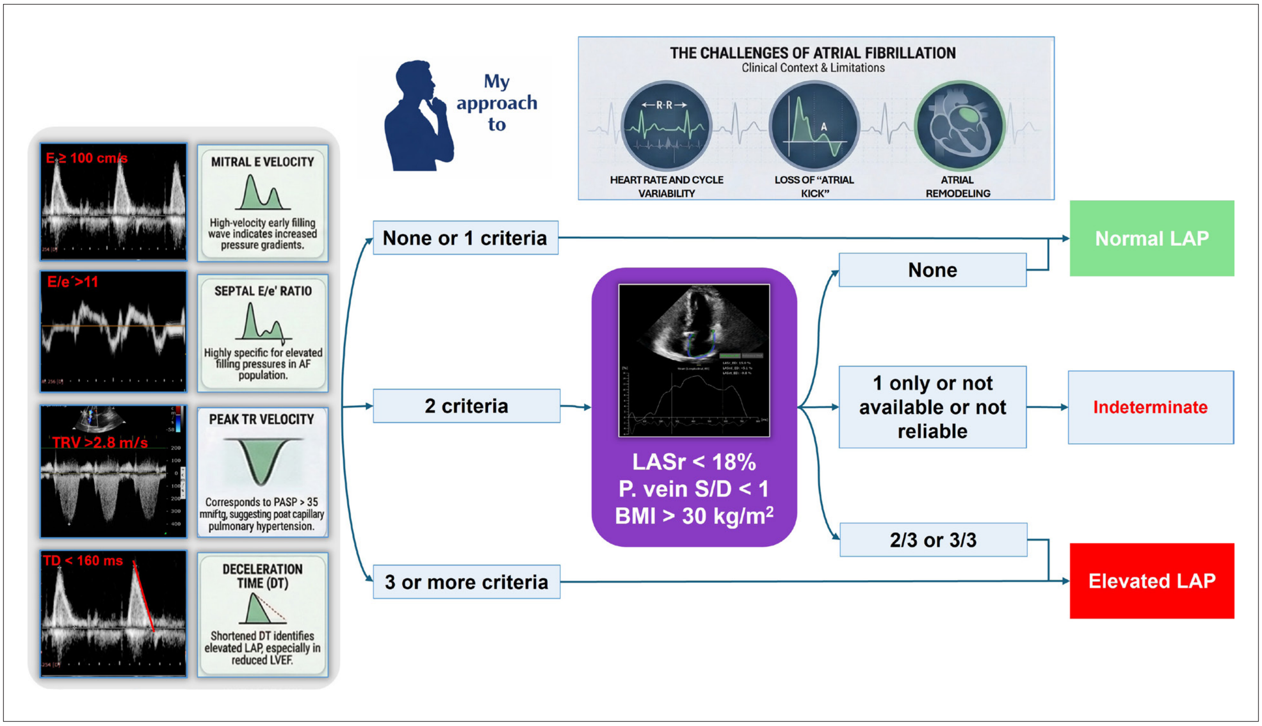


Figure 3 – *Algorithm for estimating mean LA in AF. Initial assessment is based on four parameters: mitral E velocity ≥ 100 cm/s, septal E/e′ > 11, TR velocity > 2.8 m/s (or PASP > 35 mmHg), and DT ≤ 160 ms. The presence of none or only one abnormal parameter suggests normal LAP. When two parameters are abnormal, additional markers, including LASr < 18%, S/D < 1, and BMI > 30 kg/m², are used to refine classification as normal, increased, or indeterminate LAP. BMI: body mass index; DT: deceleration time; LA: left atrium; LAP: LA pressure; LASr: LA reservoir strain; LV: left ventricle; LVEF: LV ejection fraction; PASP: pulmonary artery systolic pressure; TR: tricuspid regurgitation; AF: atrial fibrillation.*

Some studies have also proposed handgrip stress to increase afterload.[19] In selected cases, stress echocardiography may be combined with simultaneous invasive hemodynamic assessment to confirm dynamic increases in pulmonary capillary pressure, thereby supporting the diagnosis of HFpEF when noninvasive findings are inconclusive.

My Approach to stress testing: I assess changes in the E/e′ ratio and TRV at peak exercise. An increase in average E/e′ > 14 or TRV > 2.8 m/s (or > 3.2 m/s in some studies to improve specificity) during exertion indicates dynamic increase of filling pressures and supports the diagnosis of HFpEF not evident at rest (Table 4; Video 4; Video 5).

Lung ultrasound (LUS) and venous excess ultrasound

LUS and the venous excess ultrasound (VExUS) score have emerged as complementary tools for the assessment of congestion. LUS identifies B-lines as markers of interstitial edema, whereas VExUS integrates inferior vena cava assessment with Doppler interrogation of intra-abdominal veins to characterize systemic venous congestion.

Although these methods do not replace diastolic function analysis, they expand bedside hemodynamic evaluation and may reinforce the suspicion of increased filling pressures in complex clinical scenarios.[4]

Artificial intelligence (AI) in the assessment of LV diastolic function

AI has emerged as a promising tool in the assessment of diastolic dysfunction and HFpEF, particularly due to its ability to integrate multiple echocardiographic and clinical variables into predictive models that outperform isolated parameters.

Machine learning algorithms can identify subtle phenotypic patterns, reduce the rate of indeterminate cases, and improve the estimation of filling pressures. Although still undergoing broad validation, AI is expected to function primarily as a decision-support tool, refining traditional algorithms without replacing the clinical judgment of the echocardiographer.[4,20]

What should be included in the report?

The echocardiographic report of diastolic function should address a clear clinical question rather than simply reproduce an algorithm. Classification as grade I, II, III, or indeterminate is insufficient on its own; it is essential to explicitly state whether there is consistent evidence of increased filling pressures and to describe the reasoning underlying this conclusion.

The echocardiographer should integrate available parameters and clearly articulate the interpretative logic, presenting key data alongside a direct and accountable conclusion. A high-quality report is one that informs clinical

Table 4 – Indications for diastolic stress testing and invasive hemodynamic assessment

Clinical condition	Indication/Purpose
Dyspnea with indeterminate HF despite baseline refinement	Clarify LV filling pressure behavior under stress conditions
Exercise intolerance (NYHA class II/III) with normal or inconclusive resting echocardiography	Detect dynamic elevation of LV filling pressures
Persistent symptoms after mitral valve repair or TEER	Evaluate residual or exercise-induced increase of filling pressures
Subtle clinical findings discordant with a “normal” resting echocardiography	Reproduce symptoms and assess hemodynamic response under stress
When to consider invasive hemodynamic assessment	**Purpose**
Indeterminate echocardiographic findings with high pre-test probability	Confirm diagnosis through cardiac catheterization
Persistent clinical suspicion despite noninvasive testing	Document dynamic increase of pulmonary capillary wedge pressure

HF: heart failure; LV: left ventricle; NYHA: New York Heart Association; TEER: transcatheter edge-to-edge repair.

management: technical rigor has value only when it translates into clarity and actionable insight.

Conclusion

The assessment of LV filling pressures has evolved from a rigid, algorithm-driven exercise to an integrated physiological interpretation. The 2025 ASE update provides greater flexibility, allowing adaptation of the assessment according to age and comorbidities.

Rather than representing a purely mechanical application of predefined criteria, this evaluation should be understood as the structured integration of physiological data in support of clinical decision-making. We measure velocities and deformation, but our ultimate goal is to understand the hemodynamic mechanisms underlying symptoms.

When performed with technical rigor and contextualized interpretation, echocardiography not only estimates filling pressures but also elucidates underlying mechanisms. This ability to translate quantitative data into clinically meaningful insight underpins its central role in contemporary cardiology practice.

Author Contributions

Conception and design of the research: Alves MSL, Bonotto EH; acquisition of data: Alves MSL, Vosgerau LM, Dreckmann MV, Bonotto EH; analysis and interpretation of the data: Alves MSL, Dreckmann MV, Bonotto EH; writing of the manuscript: Alves MSL, Vosgerau LM, Dreckmann MV, Martins RD, Zanlorensi CB; critical revision of the manuscript for intellectual content: Alves MSL, Vosgerau LM, Dreckmann MV, Zanlorensi CB, Bonotto EH.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

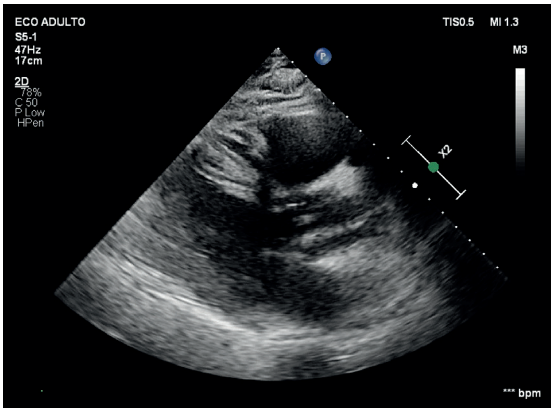
This article does not contain any studies with human participants or animals performed by any of the authors.

Use of Artificial Intelligence

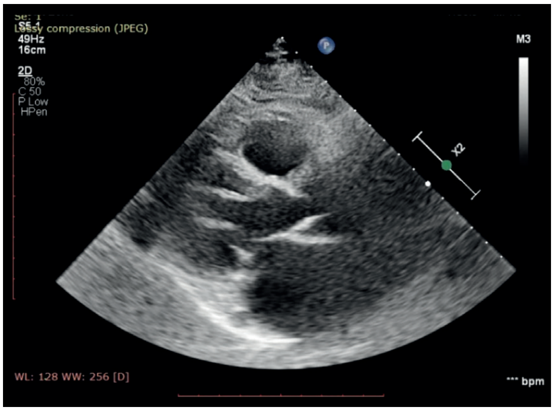
During the preparation of this work, the author(s) used ChatGPT to improve the readability and language quality of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the published article.

Availability of Research Data

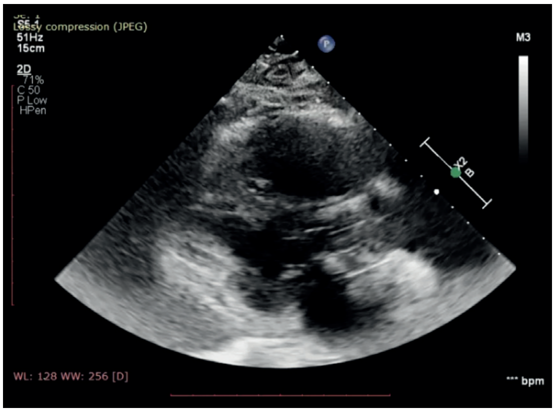
The underlying content of the research text is contained within the manuscript.



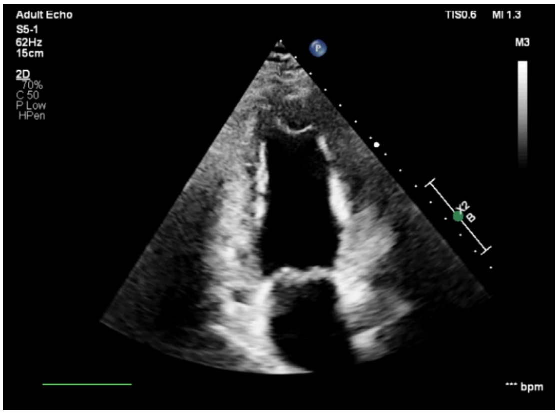
Video 1 – *HFpEF with inconclusive resting assessment, clarified by LAS. In: http://abcimaging.org/supplementary-material/2026/3902/ABCImag-2026-0026_AR_Video_1.mp4*



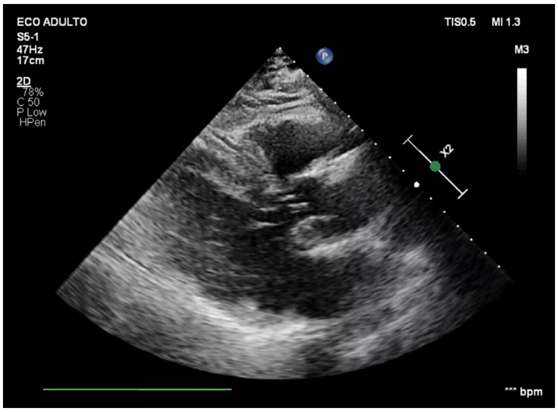
Video 2 – *AF: importance of beat averaging and the use of IVRT and LAS for refinement. In: http://abcimaging.org/supplementary-material/2026/3902/ABCImag-2026-0026_AR_Video_2.mp4*



Video 3 – *Pre-capillary pulmonary hypertension with borderline parameters and preserved LAS. In: http://abcimaging.org/supplementary-material/2026/3902/ABCImag-2026-0026_AR_Video_3.mp4*



Video 4 –*Passive leg raising demonstrating increased filling pressures in a patient with exertional dyspnea. In: http://abcimaging.org/supplementary-material/2026/3902/ABCImag-2026-0026_AR_Video_4.mp4*



Video 5 – *Diastolic stress testing with handgrip confirming increased filling pressures in unexplained dyspnea. In: http://abcimaging.org/supplementary-material/2026/3902/ABCImag-2026-0026_AR_Video_5.mp4*

References

1. Nagueh SF, Smiseth OA, Appleton CP, Byrd BF 3rd, Dokainish H, Edvardsen T, et al. Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr. 2016;29(4):277-314. doi: 10.1016/j.echo.2016.01.011.

2. van de Bovenkamp AA, Enait V, de Man FS, Oosterveer FTP, Bogaard HJ, Vonk Noordegraaf A, et al. Validation of the 2016 ASE/EACVI Guideline for Diastolic Dysfunction in Patients with Unexplained Dyspnea and a Preserved Left Ventricular Ejection Fraction. J Am Heart Assoc. 2021;10(18):e021165. doi: 10.1161/JAHA.121.021165.

3. Robinson S, Ring L, Oxborough D, Harkness A, Bennett S, Rana B, et al. The Assessment of Left Ventricular Diastolic Function: Guidance and Recommendations from the British Society of Echocardiography. Echo Res Pract. 2024;11(1):16. doi: 10.1186/s44156-024-00051-2.

4. Nagueh SF, Sanborn DY, Oh JK, Anderson B, Billick K, Derumeaux G, et al. Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography and for Heart Failure with Preserved Ejection Fraction Diagnosis: An Update from the American Society of Echocardiography. J Am Soc Echocardiogr. 2025;38(7):537-69. doi: 10.1016/j.echo.2025.03.011.

5. Lababidi H, Rahi W, Smiseth OA, Billick K, Inoue K, Khan FH, et al. New Algorithm for Estimating Left Ventricular Filling Pressure by Echocardiography. Circulation. 2025;152(7):424-35. doi: 10.1161/CIRCULATIONAHA.125.074974.

6. Nagueh SF, Middleton KJ, Kopelen HA, Zoghbi WA, Quiñones MA. Doppler Tissue Imaging: A Noninvasive Technique for Evaluation of Left

Ventricular Relaxation and Estimation of Filling Pressures. J Am Coll Cardiol. 1997;30(6):1527-33. doi: 10.1016/s0735-1097(97)00344-6.

7. Nedios S, Koutalas E, Sommer P, Arya A, Rolf S, Husser D, et al. Asymmetrical Left Atrial Remodelling in Atrial Fibrillation: Relation with Diastolic Dysfunction and Long-Term Ablation Outcomes. Europace. 2017;19(9):1463-9. doi: 10.1093/europace/euw225.

8. Ahmeti A, Bytyçi FS, Bielecka-Dabrowa A, Bytyçi I, Henein MY. Prognostic Value of Left Atrial Volume Index in Acute Coronary Syndrome: A Systematic Review and Meta-Analysis. Clin Physiol Funct Imaging. 2021;41(2):128-35. doi: 10.1111/cpf.12689.

9. Cameli M, Lisi M, Giacomin E, Caputo M, Navarri R, Malandrino A, et al. Chronic Mitral Regurgitation: Left Atrial Deformation Analysis by Two-Dimensional Speckle Tracking Echocardiography. Echocardiography. 2011;28(3):327-34. doi: 10.1111/j.1540-8175.2010.01329.x.

10. Inoue K, Khan FH, Remme EW, Ohte N, García-Izquierdo E, Chetrit M, et al. Determinants of Left Atrial Reservoir and Pump Strain and Use of Atrial Strain for Evaluation of Left Ventricular Filling Pressure. Eur Heart J Cardiovasc Imaging. 2021;23(1):61-70. doi: 10.1093/ehjci/jeaa415.

11. Lundberg A, Johnson J, Hage C, Bäck M, Merkely B, Venkateshvaran A, et al. Left Atrial Strain Improves Estimation of Filling Pressures in Heart Failure: A Simultaneous Echocardiographic and Invasive Haemodynamic Study. Clin Res Cardiol. 2019;108(6):703-15. doi: 10.1007/s00392-018-1399-8.

12. Appleton CP, Hatle LK, Popp RL. Relation of Transmitral Flow Velocity Patterns to Left Ventricular Diastolic Function: New Insights from a Combined Hemodynamic and Doppler Echocardiographic Study. J Am Coll Cardiol. 1988;12(2):426-40. doi: 10.1016/0735-1097(88)90416-0.

13. Kuecherer HF, Muhiudeen IA, Kusumoto FM, Lee E, Moulinier LE, Cahalan MK, et al. Estimation of Mean Left Atrial Pressure from Transesophageal Pulsed Doppler Echocardiography of Pulmonary Venous Flow. Circulation. 1990;82(4):1127-39. doi: 10.1161/01.cir.82.4.1127.

14. Khan FH, Zhao D, Ha JW, Nagueh SF, Voigt JU, Klein AL, et al. Evaluation of Left Ventricular Filling Pressure by Echocardiography in Patients with Atrial Fibrillation. Echo Res Pract. 2024;11(1):14. doi: 10.1186/s44156-024-00048-x.

15. Diwan A, McCulloch M, Lawrie GM, Reardon MJ, Nagueh SF. Doppler Estimation of Left Ventricular Filling Pressures in Patients with Mitral Valve Disease. Circulation. 2005;111(24):3281-9. doi: 10.1161/CIRCULATIONAHA.104.508812.

16. Pagourelias ED, Mirea O, Duchenne J, Van Cleemput J, Delforge M, Bogaert J, et al. Echo Parameters for Differential Diagnosis in Cardiac Amyloidosis: A Head-to-Head Comparison of Deformation and Nondeformation Parameters. Circ Cardiovasc Imaging. 2017;10(3):e005588. doi: 10.1161/CIRCIMAGING.116.005588.

17. Inoue K, Andersen OS, Remme EW, Khan FH, Andreassen AK, Skulstad H, et al. Echocardiographic Evaluation of Left Ventricular Filling Pressure in Patients with Pulmonary Hypertension. JACC Cardiovasc Imaging. 2024;17(5):566-7. doi: 10.1016/j.jcmg.2023.12.004.

18. Borlaug BA, Nishimura RA, Sorajja P, Lam CS, Redfield MM. Exercise Hemodynamics Enhance Diagnosis of Early Heart Failure with Preserved Ejection Fraction. Circ Heart Fail. 2010;3(5):588-95. doi: 10.1161/CIRCHEARTFAILURE.109.930701.

19. Samuel TJ, Beaudry R, Haykowsky MJ, Sarma S, Nelson MD. Diastolic Stress Testing: Similarities and Differences between Isometric Handgrip and Cycle Echocardiography. J Appl Physiol. 2018;125(2):529-35. doi: 10.1152/japplphysiol.00304.2018.

20. Akerman AP, Porumb M, Scott CG, Beqiri A, Chartsias A, Ryu AJ, et al. Automated Echocardiographic Detection of Heart Failure with Preserved Ejection Fraction Using Artificial Intelligence. JACC Adv. 2023;2(6):100452. doi: 10.1016/j.jacadv.2023.100452.